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Tina Barton
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Prevalence of Amblyopia

MERTON C. FLOM, O.D., Ph.D., and RICHARD W. NEUMAIER, O.D.

AMBLYOPIA is a catchall term used for unexplained reduction of visual acuity. "Unexplained" means that, in spite of any refractive error being neutralized with lenses and in the absence of detectable eye disease, the acuity of the eye is still below normal. The acuity criterion for amblyopia is ill defined, but a standard often adopted is 20/40 or worse. Amblyopia almost always affects only one eye.

Reduced monocular visual acuity is but one feature of amblyopia. The amblyopic person usually has difficulty in aiming and moving the eye as well as in seeing an object when it is surrounded by other forms. These difficulties cause him to make peculiar responses on a monocular acuity test—responses which aid the experienced examiner in detecting amblyopia but may lead the inexperienced examiner to pass the amblyopic person as having normal acuity. On an acuity test, the person with amblyopia signals himself by making errors over an abnormally large range of letter sizes (even though he may correctly read some of the smallest letters). He tends to miss letters in the middle of the row and more often correctly reads those at the ends. He frequently reads letters out of order, and he has more difficulty reading letters when their spacing is less than one letter apart.

Most persons with amblyopia have a significant refractive error, but neutralization of the error with lenses permits them to have essentially normal acuity when both eyes are open. Their everyday perception of depth is generally unaffected because nearly all cues to depth perception are monocular, and binocular cues (which many amblyopic persons lack) add little in ordinary visual situations. Since amblyopia affects central and not peripheral vision, the extent of the binocular field of vision is not limited by amblyopia. If the amblyopia is associated with an "eye turn" (strabismus), as is often the case, then the lateral extent of the binocular visual field tends to be smaller for "crossed eye" (convergent strabismus) and larger for "wall eye" (divergent strabismus).

These characteristics of amblyopia point up the difficulties amblyopic persons may have when attempting to see with the affected eye—a temporary situation if the good eye is simply covered, a more permanent problem if the normal eye is lost or severely damaged. The visual difficulties of the amblyopic person are thus more potential than actual.

The most universally accepted view of the origin of amblyopia is an amalgamation of ideas proposed by Claude Worth (*1*) and Bernard Chavasse (*2*). In substance, these authors stated that amblyopia is acquired in childhood as a consequence of not using one eye because it is "turned" (strabismus) or because it has a refractive error very different from that of the other eye (anisometropia). Acceptance

Dr. Flom is associate professor of physiological optics and optometry, and Dr. Neumaier is a clinic instructor, University of California School of Optometry, Berkeley. *This paper is an elaboration of one presented to the American Academy of Optometry on December 12, 1964, in Columbus, Ohio.* *The study was supported in part by a Public Health Service grant (NB 4242) from the National Institute of Neurological Diseases and Blindness.*

Data were made available to the study through efforts of James A. Collins, assistant superintendent of schools, Lafayette, and Kay Dorris, Lafayette health consultant (Lafayette School District data); Dr. Henry B. Peters, director of Berkeley's optometry school clinics (Orinda Union School District data); and Dr. Kenton E. Kerr, clinic instructor at the school of optometry (optometry clinic data).

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of this disuse notion is reflected in present-day use of the term "amblyopia ex anopsia" (literally, blindness from disuse of vision). Although the Worth-Chavasse view on the origin of amblyopia is plausible and widely accepted, there is little evidence to prove its correctness.

In spite of an enormous literature on amblyopia, there are remarkably few papers on prevalence, and only a small proportion of these apply to the general population of adults or children. Studies on the frequency of amblyopia have been based mainly upon three kinds of samples: (*a*) inductees for U.S. military service, chiefly Army, (*b*) clinical patients seeking eye care, and (*c*) grade school children and preschoolers. Interestingly, the most widely quoted prevalence figures are based upon military samples, even in papers dealing with amblyopia in children. The following quotation by Allen (*3*) is illustrative:

> How common is amblyopia? Some idea of its frequency is given by an analysis of 60,000 military selectees made during the last World War. Of these healthy young Americans, more than three percent were found to have one eye in which the best vision with lenses was less than half the normal standard of 20/20. . . .
>
> These statistics indicate that over four million Americans are suffering from some degree of amblyopia which could have been prevented. By the same token, about 100,000 children's eyes are passing beyond the help of treatment each year.

Apart from the misleading implication that 20/40 vision is only half as good as 20/20—on the American Medical Association's scale (*4*) 20/40 is 85 percent as good as 20/20—and the unsupported claim of an age limit for the successful treatment of amblyopia, Allen clearly has taken the prevalence of amblyopia among men drafted into the U.S. Army in World War II and applied it not only to the total population of Americans in 1956 but to all 7-year-old Americans in that year. In the absence of data for the general population, many authors have resorted to the prevalence of amblyopia among U.S. Army draftees and assumed it could be generalized to other populations.

Purpose of Paper

The purpose of our paper is to (*a*) analyze previous prevalence studies in terms of their applicability to the general population, (*b*) report on the prevalence of amblyopia in 1,561 kindergarteners and 1,201 children in grades 1 through 6, and (*c*) describe how changing the acuity criterion affected the prevalence of amblyopia in these school children and in 7,017 adult eye patients.

Previous Studies

Military inductees. Theodore and associates (*5*) reported on newly inducted soldiers entering Army basic training during World War II whose vision was screened to determine their suitability for flying duty, attendance at a U.S. Army Air Forces service school, regular Army duty, or limited service. Of 190,912 soldiers, 4.0 percent had amblyopia, defined as 20/50-or-worse acuity in one eye, or both, with the best possible corrective lenses. The authors stressed that their data did not represent a "cross section of the eyes of American men between the ages of 18 and 36 . . . "

Downing (*6*) personally examined 60,000 selectees reporting to a U.S. Armed Forces induction station to establish acceptability for military service under World War II mobilization regulations. Using the same acuity criterion as Theodore and associates (20/50-or-worse acuity), he found 3.2 percent with amblyopia. Although Downing was aware "that the incidence of the various conditions recorded here can be applied only to a comparable group, and not to the population at large," he nonetheless extended his own figures on selectees (draftees) to apply to all men of military age in the United States. He did not, however, assert that they were applicable to women or children.

During World War II, Glover and Brewer (*7*) studied 21,446 men, 17 to 44 years old, from 10 Pennsylvania counties. Using 20/70-or-worse acuity with corrective lenses as the criterion, they found amblyopia in 2.4 percent of their inductees. They reported that amblyopia was unassociated with family income or nationality, but did not present supporting data.

The extent to which malingering was looked for and found in these studies is relevant. Downing (*6*) reported doing tests for suspected malingerers, but Glover and Brewer (*7*) apparently did not. In the study by Theodore and

associates (*5*), "almost all" of the amblyopic subjects without strabismus or high refractive error (only one-third of their sample) were checked for possible malingering. "Relatively few malingerers or men with hysterical amblyopia were encountered. . . ." Moreover, the authors expressed the belief that "The tendency of examiners to classify a man as a malingerer merely because they can find no cause for the supposedly impaired vision is to be condemned except in rare instances."

A specific investigation of World War II inductees for possible feigning of ocular defects was made by Agatston (*8*). He estimated such malingering at 0.5 to 3.0 percent and stated that "While in private practice the veracity of the patient is seldom questioned, in Army induction examinations the honesty of the candidate must frequently be proved." The aim of the "positive" malingerer at an induction examination is, according to Agatston, to evade all military service or to obtain a limited, or perhaps a noncombatant, status. Bona fide monocular amblyopia of 20/40-or-worse acuity was found by Agatston in only 1.8 percent of 2,400 consecutive inductees who received thorough reexaminations for possible malingering. This figure of 1.8 percent may be a better indicator of the true prevalence of amblyopia among World War II inductees than the prevalences reported in studies in which malingering was not so carefully considered.

The rapid screening of millions of men during World War II would be expected to yield frequent errors in identifying amblyopia. If a man's acuity could not quickly be improved by lenses to 20/40 and could not be explained by a detectable injury or disease, then classifying him as amblyopic would only result in his qualifying for some form of limited service. This class of error appears to be more acceptable than placing a man with impaired vision in a military position in which his eyesight could affect the safety of his fellows.

A phenomenon observed during World War II probably tended to make all samples of selectees decidedly unrepresentative of the general population of male adults of military age. A significant proportion of younger men chose to enlist for duty in special branches of the military, such as the Navy, Marine Corps, and Coast Guard, in preference to the seeming certainty of being drafted into the Army to become a foot soldier. Those who tried for such enlistment but failed to meet the higher vision standards that were required characteristically waited to be called into the Army. This phenomenon would tend to bias all samples of selectees during World War II with an accumulation of men having vision problems, including amblyopia.

All these factors contributing to a high prevalence of amblyopia in wartime were either absent or minimized in a recent study by Helveston (*9*). He reported on 9,000 men, primarily enlistees but including some selectees, who were examined during peacetime in all branches of the Armed Forces except the Coast Guard. Using the same procedure and acuity criterion as Downing (*6*) and working at the same examining station, Helveston found a prevalence of amblyopia of 1.0 percent—only one-third of Downing's figure for World War II selectees.

Clinical patients. People with vision problems seek eye examinations more frequently than people with normal vision. In a clinical sample of eye patients, one expects, therefore, to find a larger proportion of vision defects than in a general population. Thus, the prevalence of amblyopia observed in clinical samples is expected to be higher than in the general population.

In 1959, Cole (*10*) reported on 10,000 consecutive patients whom he examined in Nottingham, England, under the supplementary ophthalmic service of the National Health Service. The examination was free to these patients. Cole stated that most of them had some ocular complaint. Moreover, during the course of Cole's study, additional young children suspected of having amblyopia were referred to him as a result of his informing his colleagues of the implications of amblyopia. On an American acuity chart, Cole's criterion for amblyopia was 20/50-or-worse acuity for one eye with the other eye at least two Snellen lines better. The observed prevalence of amblyopia in his clinical sample was 5.3 percent. Cole concluded that " . . . *of every* 1,000 *children born*, 53 *fail to develop normal binocular vision*," even though he was working with a clinical sample in which his youngest patient was 4 years old.

Cholst and associates (*11*) went over the records of 2,986 children, mostly over 7 years of age, who were examined at two eye clinics supported by the Bureau for Handicapped Children of the New York City Department of Health. These authors did not give an acuity criterion for amblyopia, but amblyopia was noted in the records of 4.7 percent of these children.

In 1954, de Rötth (*12*) tabulated the eye defects for 1,000 consecutive new patients in his private ophthalmological practice in Spokane, Wash. Most of his patients were over 40 years old; only a small number were of military age. According to de Rötth, there were 45 cases of amblyopia (2.25 percent of the 2,000 eyes) with vision less than 20/40. Based on the frequency of amblyopia among these 1,000 patients, the prevalence would amount to 4.5 percent. The truly clinical composition of his sample is shown by the author's report that only 50 of his patients (5 percent) were found to have no ocular defect. Thus, de Rötth's study, not unlike other clinical studies, indicates the prevalence of amblyopia among people with ocular defects.

An illustrative comparison of a military and clinical sample is provided in a brief statement by Irvine (*13*). He reported the prevalence of amblyopia among U.S. Air Corps personnel at discharge from the service to be only 1 percent; among those for whom glasses were prescribed at the Drew Field eye clinic, however, the prevalence was 4 percent.

School children and preschoolers. Because of compulsory education, most children of school age are in school, and therefore studies on the prevalence of amblyopia in children are usually done in public schools. Attempts have also been made recently, however, to uncover amblyopia in preschoolers.

In an extensive study, McNeil (*14*) estimated the prevalence of vision defects, including amblyopia, among all children in an industrialized English county borough of about 75,000 people by reviewing the records of children who attended an ophthalmic clinic in the area. The majority of children seen in the clinic were referred to it as a result of periodic vision testing in the borough's schools (referral criteria not specified). Attendance at the ophthalmic clinic, however, was not required, and some children who failed the school screening test went elsewhere, or nowhere, for professional attention. Thus, as McNeil noted, if the prevalence of amblyopia among the borough's children were based only on its frequency among children seen in the ophthalmic clinic, his estimate would tend to be low. On the other hand, McNeil does not state to what extent children with eye problems from outside the borough's schools attended the ophthalmic clinic. If they attended in significant numbers, the estimated prevalence of amblyopia for the borough's children would be high. McNeil's results must be interpreted in the light of these two opposing factors.

The ophthalmic clinic staff identified 189 children between the ages of 9 and 15 years as having amblyopia of 20/30-or-worse acuity. Relative to the total number of patients 9 to 15 years old seen in the clinic (758), 25 percent had amblyopia of 20/30-or-worse acuity. But, relative to the estimated population of children 9 to 15 years old in the borough (6,965), 2.7 percent had amblyopia. Interestingly, the prevalence of amblyopia among boys was approximately one-third higher than among girls ($P<0.05$ by chi-square).

In a preliminary study aimed at establishing the prevalence of amblyopia in 3-year-olds, da Cunha and Jenkins (*15*) reported on 301 "normal" children examined at a maternity and child welfare center in England. The Sjögren hand test (to which 31 percent of the children failed to respond) and the cover test were performed by an orthoptist; retinoscopy (to measure the refractive error) was done by an ophthalmologist. Amblyopia was defined as a "difference of more than one Snellen type line between the visual acuity of both eyes." Visual acuity of 20/60 in each eye was considered normal for 3-year-olds. Only three children were found to have amblyopia by the acuity test. "Assessment of fixation by the cover test" disclosed two additional cases. These five children comprised 1.7 percent of the sample.

A communitywide vision screening program for the detection of amblyopia in preschool children in Orange County, Calif., was reported by Russell and associates (*16*) in 1961. Of about 6,500 preschool children in the community, 1,572 children between 3 and 6 years old

were brought in by their parents in response to publicity. These children probably did not represent the general population of preschoolers in the county. The screening, done by lay volunteers, consisted of general observation of the children, the recording of eye symptoms, and the testing of acuity with E's. The acuity test was considered a failure when there was a difference between the eyes in excess of one line on the Snellen chart for any child, or acuity of 20/50 or worse in either or both eyes for 3-year-olds, 20/40 or worse for 4-year-olds. A total of 335 children failed one or more parts of the screening and were referred for an eye examina-

Table 1. Prevalence of amblyopia in various samples from previous studies

Author and date of study	Study population	Criterion	Percent of population
Military inductees:			
Theodore and associates, 1944.	Newly inducted soldiers (190,012) entering Army basic training; screened to establish type of duty.	20/50 or worse	4. 0
Downing, 1945	Author personally examined 60,000 selectees reporting to Armed Forces induction station to establish acceptability for service under existing mobilization regulations.	do	3. 2
Glover and Brewer, 1944.	Men 17 to 44 years old (21,446) screened at an induction station to establish acceptability for service.	20/70 or worse	2. 4
Agatston, 1944	A specific study of ocular malingering among 2,400 inductees in which only bona fide cases of monocular amblyopia were counted.	20/40 or worse	1. 8
Helveston, 1965	Primarily enlistees (9,000) for all branches of the Armed Forces (except the Coast Guard) examined during peacetime—same station and same criteria as Downing's wartime study of selectees.	20/50 or worse	1. 0
Clinical samples:			
Cole, 1959	Author examined 10,000 consecutive patients who presented themselves to him for eye care under the British National Health Service.	do	5. 3
Cholst and associates, 1962.	Authors surveyed records of 2,986 children (mostly over 7 years of age) examined at two eye clinics of the Bureau for Handicapped Children, New York City Department of Health.	Physicians' diagnosis	4. 7
de Rötth, 1945	Author personally examined 1,000 consecutive new patients presenting themselves to his private ophthalmological practice.	20/50 or worse	4. 5
School and preschool children:			
McNeil, 1955	Author counted records of amblyopic children, ages 9–15 years, examined in an ophthalmic clinic in an English county borough. Referrals chiefly from school screening. The population of children of corresponding ages within borough estimated to be 6,965.	20/30 or worse	2. 7
da Cunha and Jenkins, 1961.	Normal 3-year-olds (301) examined at a maternity and child welfare center in England.	Difference between eyes $\geqq$2 acuity lines.	1. 7
Russell and associates, 1961.	Lay volunteers screened 1,572 preschool children, ages 3 to 6 years, who were offered to the project. Reported incidence of 0.6 percent adjusted to 1.3 percent for children referred for care but not seen professionally.	Physicians' diagnosis	1. 3
Vaughan and associates, 1960.	Health records of 25,000 public school children, grades kindergarten—12, reviewed for failure on nurses' acuity tests. Only children not already under care were examined for amblyopia.	Difference between eyes $\geqq$2 acuity lines.	. 6

tion, but only 167 children (50 percent) received professional attention. In all, 10 children were diagnosed as having amblyopia ex anopsia. Unfortunately the criterion for amblyopia was not specified, but presumably the physicians used one in the region of 20/40 to 20/50 acuity. These 10 children with amblyopia comprised 0.6 percent of all children screened. It is reasonable to believe that there was a smaller proportion of children with amblyopia among those children who did not obtain professional attention than among those who did. Nevertheless, on the assumption that the proportions were equal and assuming that no one with amblyopia passed the screening, the prevalence of amblyopia would become 1.3 percent.

In a study by Vaughan and associates (*17*), health records of 25,000 children in San Jose, Calif., in grades kindergarten through 12 were reviewed and pulled if there was a notation of "at least a two-line difference in the visual acuity between the two eyes" as determined by routine screening by the school nurse. Although it is not stated how many children failed by this criterion, 489 were subsequently examined by an orthoptic technician, who diagnosed 132 as having amblyopia ex anopsia. The orthoptist referred 71 other children for further study by Vaughan and Cook (ophthalmologists), who found an additional 24 cases of amblyopia. In all, 156 children with amblyopia were identified in the study. Thus, 0.6 percent appears to be the prevalence of newly discovered amblyopia in 25,000 school children in a large California city of heterogeneous population.

A study expressly conceived to identify previously undetected amblyopia was reported by Gilman (*18*). Of 6,553 kindergarten and first-grade children screened by school nurses in Marin County, Calif., only 12 children (0.2 percent) were found upon later examination by eye specialists to have amblyopia (20/40-or-worse acuity) which had not been known to exist before the children entered school.

Bangerter, director of one of the world's largest centers for treatment of amblyopia, in St. Gallen, Switzerland, has estimated the prevalence of amblyopia at 1 percent in the general population and at somewhat more than 2 percent in localities of mixed industrial character (*19*). Since the basis of these estimates and the composition of the samples are not given, it is not possible to fit these prevalences into the framework of the other studies described here and summarized in table 1.

Table 2. School children in 2 California school districts investigated for amblyopia

Availability to study	Enrolled in Lafayette School District kindergarten, 1959–63 (N=2,055)	Enrolled in Orinda Union School District grades 1–6, 1954 (N=1,221)	Total (N=3,276)
Available	1,561	1,201	2,762
Screened in kindergarten by optometrists	1,521	1,201	2,722
Under professional care, not screened	40	0	40
Not available	494	20	514
Not screened, erroneously reported under care	9	0	9
Not screened, absent from school	241	8	249
Not screened, parental refusal	19	12	31
Moved from district before analysis	225	0	225

Present Investigation

Our retrospective investigation is based on two populations of children from two upper-middle-class school districts and a population of patients from a university eye clinic.

School children. One population of children consisted of 2,055 kindergarteners who entered the Lafayette (Calif.) School District during the fall of the years 1959 through 1963. It was the policy in this district for entering kindergarteners not under the care of a private eye practitioner to be screened in their schools during the fall semester by optometrists. Available for study from Lafayette were 1,561 kindergarteners: 1,521 who were screened and 40 who were under professional care (table 2). Of 494 children not available for study, 9 were not screened because they had been erroneously reported to be under the care of an eye practitioner, 241 were absent from school on their scheduled day for screening, 19 had parents who refused to allow vision screening (usually for religious reasons), and 225 had moved out

of the district (their health records were not available when the analysis was made in 1964).

A second population consisted of all the children in grades 1 through 6 in the Orinda (Calif.) Union School District in 1954. Of these 1,221 children, 1,201 were screened and thereby comprised the Orinda sample (table 2). Not available to the study were eight children who were absent from school on the days of screening. The number not screened was small because the screening was done on several different days at each school, and an effort was made to screen every child who was absent from school on his scheduled screening day. An additional 12 children were unavailable because their parents refused to allow any health tests for religious reasons. Information on children who had moved from the Orinda district was available to the study because a record of their vision data was retained in the district.

The screening in both samples was administered by optometrists. It consisted of tests of monocular visual acuity (single projected E's), refractive error in the vertical and horizontal meridians (retinoscopy), binocular coordination at distance and near (objective cover test with prisms) and ocular disease (ophthalmoscopy and external examination). A committee of public health officers, ophthalmologists, and optometrists has called this screening technique the "modified clinical technique" and has found it to be highly effective for vision screening of school children (*20*).

A child failed the acuity test if he had 20/40-or-worse acuity for either eye with his glasses, or without glasses if none were worn. In the Lafayette sample, clinical reports were requested from private practitioners for all children who failed the screening as well as for all children not screened because they were under professional care. In Orinda, the screening tests were given both to children not under care and to children already under professional care. Orinda children who failed the screening were referred to the University of California School of Optometry or to the Stanford University Department of Ophthalmology for a complete vision examination. A control group of 221 children had been randomly selected from the rolls of the district by the assistant superintendent of schools before the screening was begun. These children were given complete vision examinations in which the examiner looked for vision defects that might have been missed in the screening with the modified clinical technique.

The prevalence of amblyopia was calculated for several different acuity criteria. One of these was monocular visual acuity of 20/40 or worse when the refractive error was neutralized by lenses and there was a difference in acuity between the two eyes of more than one Snellen line (the acuity notations on the abscissa of figure 1 were considered as consecutive Snellen "lines"). Table 3 shows that by this criterion amblyopia could be attributed to 15 of 1,561 kindergarteners (1.0 percent) and to 14 of 1,201 children in grades 1 through 6 (1.2 percent).

Table 3. Prevalence of amblyopia in school children in 2 California school districts

Basis for diagnosis	Lafayette sample (N=1,561)		Orinda sample (N=1,201)		Total sample (N=2,762)	
	Amblyopia (N=15)	No amblyopia (N=1,546)	Amblyopia (N=14)	No amblyopia (N=1,187)	Amblyopia (N=29)	No amblyopia (N=2,733)
Passed acuity test by modified clinical technique	0	1,478	0	1,063	0	2,541
Failed acuity test, followup report received	5	28	13	120	18	148
Failed acuity test, no followup report received	2	8	1	4	3	12
Under professional care, followup report received	8	32	0	0	8	32
Percent of sample	1.0	99.0	1.2	98.8	1.0	99.0

This difference in observed frequency is not statistically significant by the chi-square test (P is about 0.6). In the combined sample of 2,762 school children, the prevalence of amblyopia by this criterion amounts to 1.0 percent.

Of the 29 children in the total sample who were considered amblyopic, 26 had the diagnosis established by their eye practitioner, who sent a report to the child's school; 18 of these had failed the acuity screening test, and 8 were already under professional care. Three children were considered as probably amblyopic on the basis of comparing their unaided acuity with their refractive error determined by retinoscopy (table 4).

Eight children in the sample had reduced visual acuity that was not considered amblyopia since their acuity was commensurate with an existing ocular disease. Three children had lenticular opacities (cataract), two had posterior staphyloma of the choroid, one had postviral corneal scar, one optic atrophy, and one bilateral macular pigmentary degeneration.

In 1953, a symposium of ophthalomologists agreed that "visual acuity of 20/40 or less constituted a clinically significant amblyopia" (*22*). From previous studies, it is clear that different acuity criteria have been used in research on amblyopia. It is therefore reasonable to ask in what way prevalence of amblyopia is related to the acuity criterion used to define it.

In our study, 29 of the 2,762 children (1.0 percent) had amblyopia when the criterion was 20/40-or-worse acuity with more than one line difference between the two eyes. If the cutoff acuity had been 20/50, the prevalence would have been 0.7 percent. Adopting progressively worse acuities as a criterion leads to regularly lower occurrences of amblyopia as shown by the lower cumulative frequency curve in figure 1. If the requirement of more than one line difference between the eyes is neglected, the prevalence of amblyopia for the 20/40-or-worse criterion increases from 1.0 percent to 1.4 percent.

Since the acuity level for failure by the modified clinical technique was set at 20/40, it is not possible to ascertain the number of children who would have had amblyopia for a criterion of 20/30-or-worse acuity, 20/25-or-worse acuity, and so on. McNeil (*14*), however, using 20/30-or-worse acuity as his criterion for amblyopia with no required acuity difference between the eyes, found that 2.7 percent of children between 9 and 15 years old had amblyopia. Figure 1 shows that the frequency McNeil observed plots as a reasonable extrapolation of the upper fre-

Table 4. Visual acuity, refractive errors, and probable amblyopia in the 15 children who failed vision screening and had no followup report

Screening acuity [1]	Refractive error		Expected acuity	
	Vertical	Horizontal	Unaided [2]	With lenses [3]
Lafayette School District:				
20/25	+1.00	+1.00	20/20	20/25
20/60	**+2.50**	**+2.50**	**20/25**	**[4] 20/40**
20/70	**+2.00**	**+ .25**	**20/40**	**[4] 20/40**
20/20	+.50	plano	20/20	20/20
20/25	+.50	+.50	20/20	20/25
20/40	−.25	−.25	20/25	20/30
20/25	+.50	+.50	20/20	20/25
20/40	−1.00	−1.75	20/70	20/20
20/30	+1.25	+.50	20/25	20/25
20/50	+.50	−1.25	20/50	20/20
20/50	**+1.00**	**+.75**	**20/20**	**[5] 20/50**
20/50	+1.00	+1.00	20/20	20/50
20/25	−.50	−.50	20/30	20/20
20/50	−.75	+1.00	20/50	20/20
20/25	+1.00	+1.00	20/20	20/20
20/40	+2.00	+1.00	20/30	20/25
20/40	+1.75	+1.00	20/25	20/30
20/40	+1.50	+.50	20/25	20/30
20/40	+1.50	plano	20/40	20/20
20/20	+.75	plano	20/25	20/20
Orinda School District:				
20/20	+.50	+.75	20/20	20/20
20/70	**+1.00**	**+2.00**	**20/25**	**[4] 20/60**
20/50	**+1.50**	**+1.50**	**20/20**	**[5] 20/50**
20/50	+1.50	+2.25	20/25	20/40
20/40	−.75	+.25	20/30	20/25
20/30	+.25	+.25	20/20	20/30
20/40	−.25	−.25	20/25	20/30
20/25	−.25	−.25	20/25	20/20
20/25	−.25	−.25	20/25	20/20
20/50	−.50	−.50	20/30	20/30

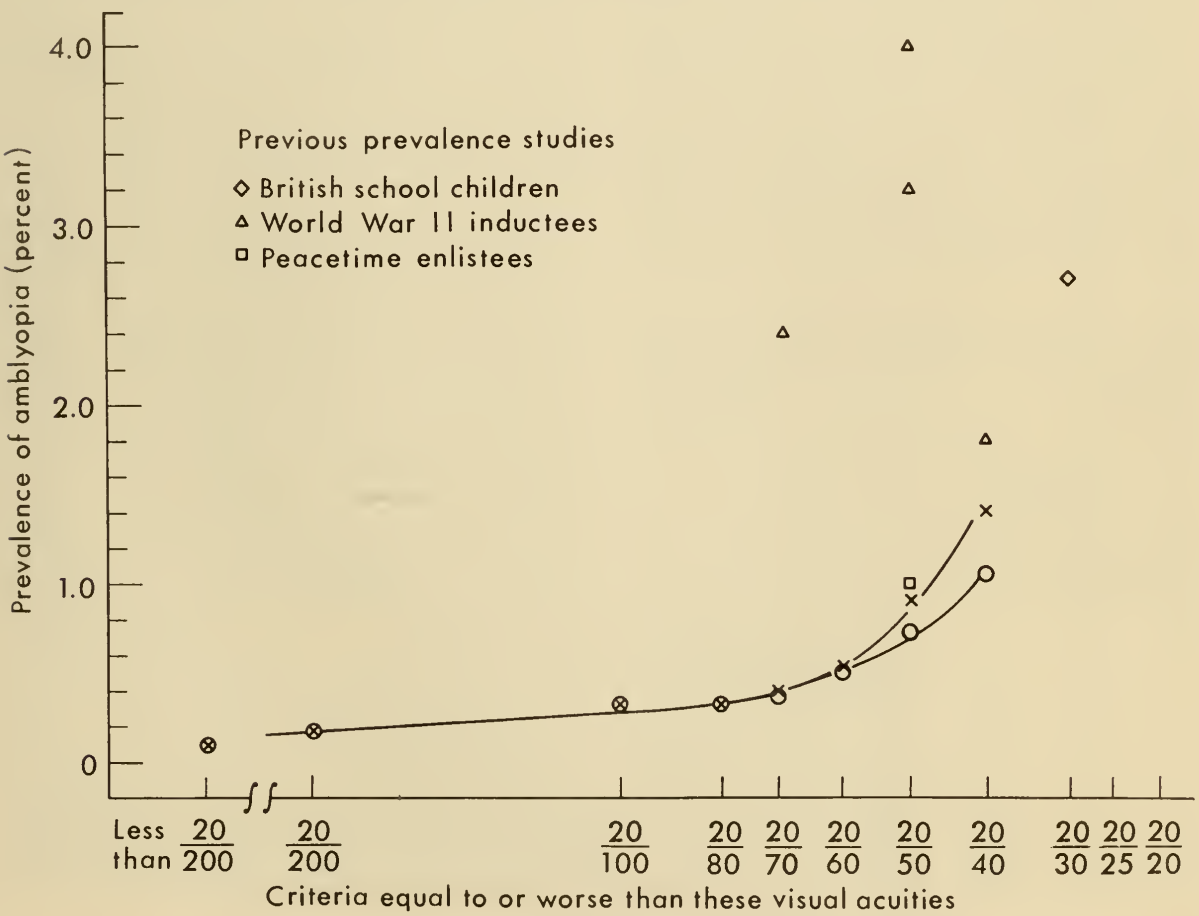
[1] By modified clinical technique.
[2] Expected unaided acuities were obtained by referring to a figure by Peters (reference 21).
[3] The expected acuity with lenses was obtained from the expected unaided acuity as well as from the acuity actually found in the screening test.
[4] 3 children counted as amblyopic had a difference in acuity between the eyes of more than 1 line.
[5] 2 children counted as amblyopic had a difference in acuity between the eyes of 1 line or less.

quency curve for the present study. Theoretically, the upper cumulative frequency curve should reach 100 percent at about 20/15 since virtually all children must have 20/15-or-worse acuity in at least one eye. The lower cumulative frequency curve should theoretically decelerate to the right of 20/40 since the requirement of more than one line difference between the eyes for a diagnosis of amblyopia limits the number of cases of amblyopia with 20/30 and 20/25 acuity and excludes cases of amblyopia with 20/20 acuity. Our study of clinical patients bears on the change in prevalence when these low grades of amblyopia are included.

Clinical patients. A study sample was selected from approximately 25,000 patients who had received free eye examinations between 1958 and 1963 at the clinic of the University of California School of Optometry in Berkeley. Patients at the clinic are students, faculty, and employees of the university, as well as people from Berkeley, Oakland, and suburban communities. About 90 percent are between 10 and 50 years old. Since a relatively large proportion of the clinic's patients over 50 years of age have acuity losses associated with senility or disease and a disproportionately large number of those under 10 years have strabismus, it was decided to restrict the sample to the ages of 10 to 50 years. All records in drawers *A* through *H* of the alphabetical clinic files were reviewed, and 7,017 persons were found to be in the appropriate age group.

To obtain a more extensive range for the cumulative frequency curve of amblyopia, the acuity criterion for amblyopia was set very

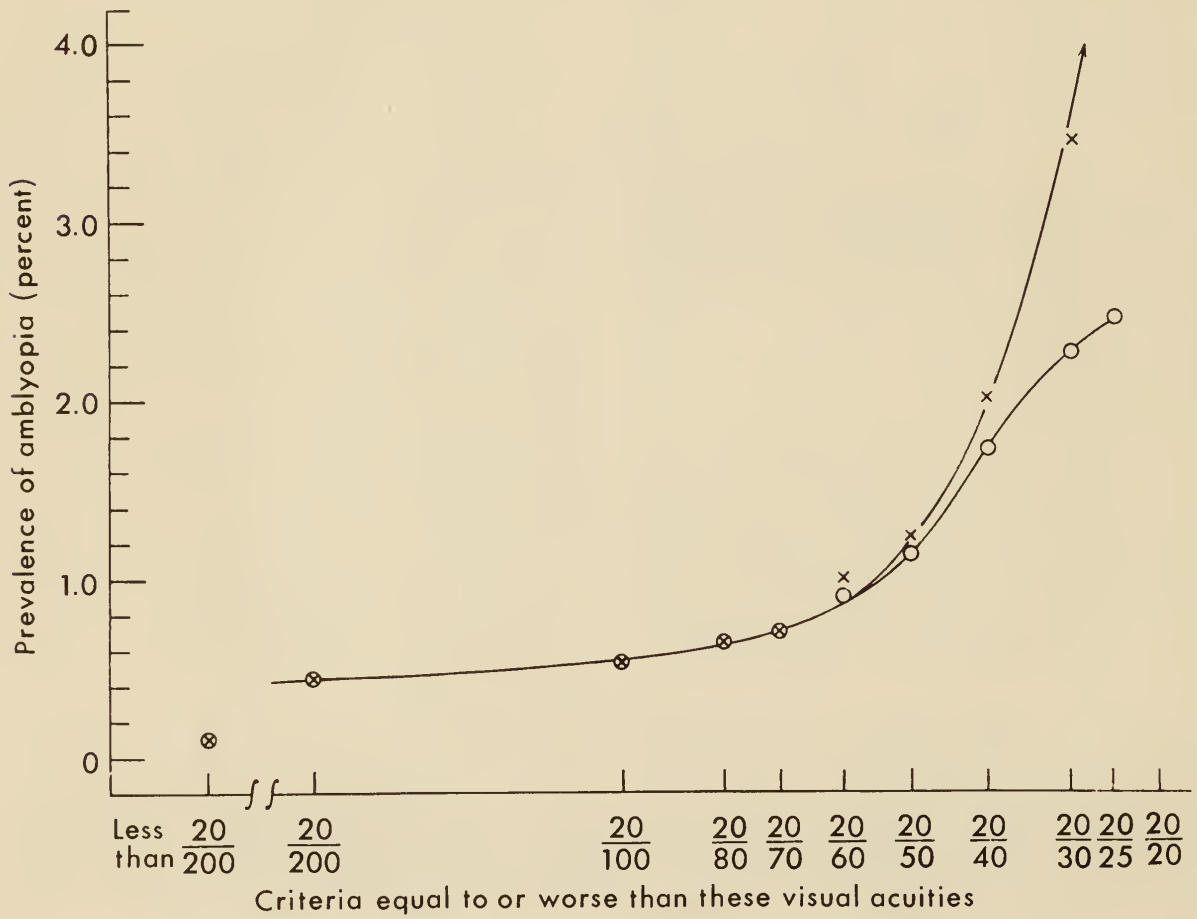
Figure 1. Prevalence of amblyopia for different acuity criteria (upper curve) and for the added criterion of more than one line difference between the eyes (lower curve) in 2,762 school children. Prevalence from other studies plotted for comparison



low—20/25-or-worse acuity (with optimum correction of the refractive error and no evidence of an existing ocular disease). The resulting cumulative frequency curves for the clinical patients (fig. 2) have the same shape as those for the school children (fig. 1), but are about 0.4 percent higher. It is interesting to note the relatively slow rise in the prevalence of amblyopia in the clinical sample in the region of 20/30 (2.3 percent) and 20/25 (2.5 percent) acuities when the criterion of more than one line difference in acuity is used. By contrast, when this difference-in-acuity criterion is not used, the prevalence is seen (fig. 2) to rise rapidly to about 3.5 percent at 20/30 and (not shown in the figure) to about 9.0 percent at 20/25. These effects are consistent with the theoretical expectations for prevalence of amblyopia.

With the amblyopia criterion of 20/40-or-worse acuity and more than one line difference between the eyes, the prevalence of amblyopia in the clinical sample is 1.7 percent. This prevalence is substantially less than is usually found in clinical samples (table 1) and probably results from the relatively large number of visually normal persons, particularly students, who come to the university clinic. Most new students and many students having difficulty preparing for examinations routinely come to the clinic for an eye examination. Although our clinical sample is undoubtedly biased in respect to amblyopia, it appears to be less so than other clinical samples.

Figure 2. Prevalence of amblyopia for different acuity criteria (upper curve) and for the added criterion of more than one line difference between the eyes (lower curve) in 7,017 eye patients



Tests with single letters. It is well known that some eyes can exhibit normal or near-normal acuity only in tests with single letters, when the interacting influence of surrounding contours is eliminated (*23*, *24*). In the present investigation, screening of the children's visual acuity was done with single projected E's; children who were given a complete eye examination were generally tested with a line or a whole chart of letters. It is therefore possible that some children had amblyopia at the time of screening but escaped detection.

In the sample of 2,762 school children, 251 passed the single-E test but failed some other part of the screening with the modified clinical technique. After a complete clinical examination, none of these children were found to have amblyopia.

A control group of 221 children was randomly selected as part of the Orinda study (*20*) to ascertain the frequency of vision defects missed with the modified clinical technique. These 221 children were given complete clinical examinations, and none who passed the acuity screening were found to have amblyopia.

Von Noorden (*24*) has reported that 29 percent of his subjects with amblyopia had 20/40-or-worse acuity with a line of letters (his criterion for amblyopia) but better than 20/40 with single letters. Since von Noorden's sample consisted entirely of persons previously treated for strabismic amblyopia, a large number of them would be expected to exhibit significantly better isolated-letter acuity than whole-line acuity (a common observation in amblyopic persons who have been treated). Among all persons with amblyopia, including persons with nonstrabismic amblyopia and untreated amblyopia, a smaller number of undetected cases is expected. It is estimated that in not more than 0.2 percent of the present sample of children was amblyopia undetected because of testing with single letters.

Additional observations. Information available for the Lafayette sample indicates that only 40 (2.6 percent) of 1,561 kindergarteners had received professional eye care before entering school, a surprisingly low figure for an upper-middle-class school district. In contrast, half of the amblyopic children (8 of 15, table 3) had already received eye care before entering kindergarten. This difference in preschool eye care for children with and without amblyopia is significant by chi-square at the 0.001 level. The children with amblyopia obtained preschool eye care 25 times more often than the others. It appears that the major reason they obtained care was strabismus since four-fifths of the 40 kindergarteners who had received previous eye care had strabismus, a more obvious condition than amblyopia.

How many of the nonamblyopic kindergarteners might have had amblyopia at the time of screening if they had not received professional attention before entering school? To answer this question, the parents and eye practitioners were asked about the child's early eye history, the kinds of treatment used, and any improvement. Results of this inquiry, summarized in table 5, show that 10 of 32 children might have had amblyopia in kindergarten if they had not previously been seen professionally. It is unlikely that the other 22 children would have had amblyopia. These conclusions are evident in most cases; they are less clear cut for the children who showed no preschool evidence of amblyopia but showed improvement in the frequency or laterality of their strabismus following treatment. If the 10 children who might have had amblyopia in kindergarten are added to the 15 kindergarteners found to be amblyopic, the prevalence of amblyopia would

Table 5. Effect of preschool vision care on prevalence of amblyopia in 32 kindergarteners

Reported preschool results	Amblyopia in kindergarteners		
	Unlikely	Possible	Likely
No evidence of amblyopia, no treatment given	12	0	0
No evidence of amblyopia, treatment did not improve strabismus	5	0	0
No evidence of amblyopia, treatment improved strabismus	5	3	2
Evidence of amblyopia, treatment improved strabismus or amblyopia	0	0	5
Total	22	3	7

be 25 of 1,561, or 1.6 percent. This proportion is the prevalence expected if none of the children had received preschool eye care.

Children found to be amblyopic in kindergarten who had not received professional eye care before entering school were considered to represent newly discovered cases. There were 7 such cases in the Lafayette sample of 1,561 kindergarteners (table 3), a prevalence of 0.4 percent. In other studies, the prevalence of newly discovered amblyopia has been found to be 0.2 percent (*18*) and 0.6 percent (*17*). Although these figures are not entirely comparable, it is seen that the rate of uncovering previously unknown amblyopia through school screening may be low.

Accurate measurement of the visual acuity of 3- and 4-year-olds is difficult (*15*, *25*). In the present study, however, all the children with amblyopia either had strabismus (38 percent), had one diopter or more of anisometropia (34 percent), or had both conditions (28 percent). Of the 122 persons with amblyopia in the clinical sample, 119 (or 98 percent) had either or both of these conditions. Elaboration of this relationship and a description of how objective tests for strabismus and anisometropia can be used to detect amblyopia in infants will be covered in a subsequent paper.

Summary and Conclusions

Amblyopia is a catchall term for unexplained reduction of visual acuity, usually in one eye. In spite of any refractive error being neutralized with lenses and in the absence of detectable eye disease, the acuity of the eye is still below normal. As long as amblyopic persons have one normal eye, their visual problems are more potential than actual.

Many public and private agencies are embarking on programs of screening, diagnosis, and treatment of amblyopia. They are motivated by the prevalence of amblyopia found in samples of World War II inductees (1.8 to 4.0 percent) and in samples of eye patients (4.5 to 5.3 percent). Prevalence in these samples, however, is higher than that expected for the general population of adults or children.

In the present investigation, 1.0 percent of 2,762 school children had monocular amblyopia of 20/40-or-worse acuity with a difference between the eyes of more than one acuity line. Newly discovered amblyopia amounted to 0.4 percent. If account is taken of those amblyopic children who were perhaps missed by screening (0.2 percent) and those children who received preschool treatment which may have prevented or eliminated an amblyopia (0.6 percent), the prevalence becomes 1.8 percent.

In a sample of 7,017 persons 10 to 50 years old who attended the clinic of the University of California School of Optometry, Berkeley, prevalence of amblyopia was found to be 1.7 percent when a criterion of 20/40-or-worse acuity with more than one line difference between the eyes was used. This proportion, substantially less than usually found in clinic samples, probably reflects the large number of visually normal persons who attend the university clinic.

Of all the amblyopic persons found in our samples of school children and patients, only a small proportion had worse than 20/200 acuity (legal blindness), and a large proportion had acuities in the region of 20/40. In this region, prevalence of amblyopia was found to change markedly with a small change in the acuity criterion.

There was no significant difference in the prevalence of amblyopia between kindergarteners and children in grades 1 through 6. Since amblyopia seems to develop only rarely after children reach school age, a similar prevalence is expected in children and adults.

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